Prevalence of *Toxoplasma gondii* Parasite and Associated Risk Factors Among The Population in Al Baha Province, Saudi Arabia: A Retrospective Study

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ABSTRACT

Toxoplasmosis is a parasite infection that presents a significant public health issue in Saudi Arabia. Retrospective research was undertaken in a tertiary hospital in Al-Baha to determine the prevalence of *Toxoplasma gondii* infection in patients from January 2017 to June 2023. Revealing an incidence rate of 22%. The study's results revealed a significant disparity in the portrayal of females and males. Females constituted a greater percentage, with 73.4%, while males comprised 26.6%. The resulting p-value was 0.02, indicating a statistically significant result. The positive cases had an older age distribution, with a mean age of 23.27 years. Conversely, the group with negative results had an average age of 15.54 years. The p-value for this comparison was 0.001, indicating a statistically significant outcome. The research also found a positive association between seropositivity and many pregnancies, namely 4 pregnancies (52.83%), as well as a history of abortion (75.5%). In addition, our study emphasizes many clinical presentations, such as developmental delay (10.5%), congenital anomalies (7.3%), seizure (5.6%), epilepsy (4%), IUGR (3.2%), and Autism (2.4%). The study suggests that healthcare authorities should contemplate the adoption of screening programs that specifically target individuals with a higher risk. Furthermore, it suggests the implementation of educational initiatives to enhance awareness, particularly among susceptible demographics.

Keywords: Toxoplasmosis; *Toxoplasma gondii*; Seroprevalence; Congenital infection

INTRODUCTION

Toxoplasma gondii (*T. gondii*) is the causative agent of a parasitic disease known as toxoplasmosis. It is a widespread and severe public health risk affecting people of all ages globally[1]. Toxoplasmosis is generally non-symptomatic and frequently goes unrecognized in immunocompetent individuals; nevertheless, congenitally infected fetuses and immuno-compromised persons are additionally at risk for health complications and death due to this illness[2]. Pregnant women exhibit heightened susceptibility to *T. gondii* infection due to the ability of the parasite to traverse the placental barrier, leading to the development of congenital toxoplasmosis[3]. The spectrum of congenital infection severity spans from asymptomatic cases to severe manifestations, encompassing a wide range of potential outcomes for the developing fetus. These outcomes may have lasting implications, particularly in terms of neurological and ocular abnormalities. Recent studies have shed light on the various factors influencing the severity of congenital infections, such as viral load and maternal immune response[4]. Immuno-compromised individuals, characterized by HIV/AIDS or immunosuppressive therapy, are at heightened susceptibility to severe and reactivated toxoplasmosis[5,6]. The compromised immune response in these individuals allows for the reactivation of latent *T. gondii* infection, leading to potentially severe clinical outcomes. In the affected populations, the infection has the potential to present as encephalitis, retinochoroiditis, or other forms of severe organ involvement, thereby posing a substantial health risk[7]. The global distribution and prevalence of *T. gondii* infection exhibit significant variation, as evidenced by recent studies[8]. This widespread exposure highlights the importance of understanding the epidemiology and impact of *T. gondii* infection on public health. The occurrence of a high prevalence of a certain condition is frequently linked to various factors, including the consumption of raw or undercooked meat, proximity to cats, and exposure to water and soil that may be contaminated[9,10]. The prevalence of toxoplasmosis varies with climate, dietary and hygiene practices and geographical location. Recent studies have highlighted the influence of climate change on the distribution and abundance of oocysts, emphasizing the need for a comprehensive understanding of these environmental dynamics to effectively manage and mitigate the risks posed by oocyst-borne infections[11,12].

T. gondii infection is highly prevalent in the Middle East, which is one of the regions with the highest rates of this parasitic infection, with an overall incidence of 30%–50%[13]. The treatment for toxoplasmosis infection with drugs available today is not only prohibitively expensive and fraught with serious adverse effects but there is also the risk that the disease will return. Therefore, *T. gondii* poses a significant risk to both the general population's health and the economy of every nation[14]. However, the epidemiology of this disease in specific regions of Saudi Arabia remains largely unknown. The Al-Baha region has not been studied yet. Therefore, it is essential to conduct studies that evaluate the seroprevalence of *T. gondii* infection. The objective of this

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retrospective study conducted in a hospital setting was to evaluate the prevalence rate of *T. gondii* infection among a population of patients residing in the Al-Baha region between the years 2017 and 2023.

MATERIALS AND METHODS

Sample Size: A retrospective study was conducted using archived medical records and TORCH panel assay test outcomes, specifically for *T. gondii* infection at King Fahad Hospital in the Al-Baha region of Saudi Arabia. The authors gathered the data throughout the period spanning from January 2017 to June 2023.

Study Setting: Our research was undertaken at King Fahad Hospital in Al-Baha, Saudi Arabia. This institution has earned accreditation from the Central Board for Accreditation of Healthcare Facilities in Saudi Arabia. Serving as a vital healthcare center, King Fahad Hospital is a trusted destination for patients from surrounding clinics and hospitals, playing a key role in the region's healthcare landscape.

Study Design: A retrospective study was conducted to assess the Seroprevalence rate of *T. gondii* infection among a population of patients residing in the Al-Baha Region in Saudi Arabia, from January 2017 to June 2023. This study collected data on patients' information, from the Medical Record. we meticulously gathered data using a well-structured Excel template. The research undertaken at KFH investigated the prevalence of *T. gondii* infections in individuals across all age groups and genders.

Inclusion and Exclusion Criteria: The study included patients whose serum was analyzed using the TORCH panel assay, specifically for *T. gondii* infection, and excluded 120 patient files due to insufficient patient data. These exclusions were made to ensure the accuracy and reliability of the data collected.

Data Collection: For our data collection, we carefully set up a standardized process. We chose specific variables in advance and used a tailor-made sheet to systematically gather patient information and lab results (**Figure 1**), focusing on socio-demographic and obstetric details. We took special care to maintain the integrity and confidentiality of the data, ensuring that all the information we collected was solely for this research, with a strong commitment to privacy and ethical standards.

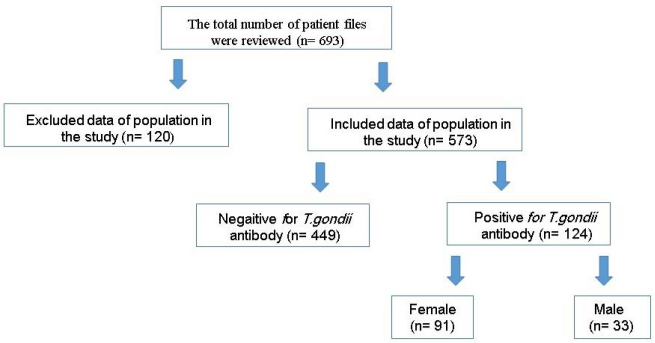

Figure 1: Flow-chart for patient selection

Statistical analysis of data: The database was concocted using Excel for data cleansing and processing., while the data analysis was achieved using version 25 of the Statistical Package for the Social Sciences. To describe the data, a descriptive analysis was performed. The use of measures of central tendency, such as the median and standard deviation, were utilized for continuous data, and measures of dispersion, such as frequency and percentage, were utilized for categorical variables. Various statistical tests were employed, including Chi-square, Fisher's exact tests, and the Mann–Whitney U test, with a significance level set at $p < 0.05$.

RESULTS

This retrospective study at King Fahad Hospital examined *T. gondii* infection in Al-Baha patients. Initially, 693 patient files were reviewed. However, 120 of these files had to be eliminated owing to insufficient or incorrectly reported data. Following these exclusions, 573 patient data were examined. **Figure 2** depicts the study's inclusion and exclusion criteria with sample size.

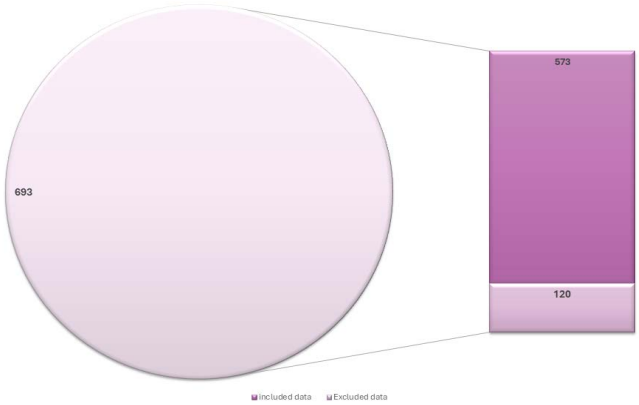

Figure 2: Included and excluded data of population in the study

The overall seroprevalence of Toxoplasmosis among the population in Al-Baha

Toxoplasmosis prevalence in Al-Baha was determined using TORCH screening tests, with a rate of 22%. 573 individuals were examined in this study, with 124 classified as Toxoplasmosis cases based on positive test results. 449 people, or 78% of the sample population, got negative test results and are control subjects. **Table 1** and **Figure 3** display the ratio of cases and controls for Toxoplasmosis prevalence.

Table 1: Prevalence of Toxoplasmosis among the studied population in Al-Baha, n = 573

Variables categories	Frequency	%
Cases	124	22
Controls	449	78
Total	573	100

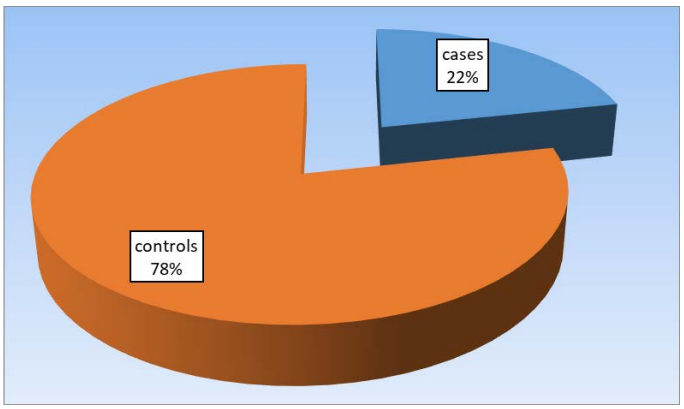

Figure 3: Prevalence of Toxoplasmosis among the studied population in Al-Baha according to Toxoplasma results

Seroprevalence of anti-*T. gondii* IgG and IgM antibodies in the studied population

The study analyzed antibody distribution in two groups of 573 people, divided into 124 cases and 449 controls. The focus is on anti-toxoplasma IgG antibodies. 97.6% (n = 121) of cases tested positive for toxoplasma IgG antibodies. Only 1.6% (n = 2) of cases tested negative for IgG antibodies. In contrast to the control group, all participants (n = 449) tested negative for IgG antibodies. Only 0.8% (n = 1) of cases have been studied, so there is a lack of available data on IgG. The DS-EIA-ANTI-TOXO-G kit being unavailable led to a lack of corresponding data. The analysis of *T. gondii* IgM antibodies was used to identify the infection status. 21.1% (n = 121) tested positive for IgG, while 78.7% (n = 451) tested negative. 0.2% (n = 1) had missing data. The P-value < 0.001 shows a significant difference in IgG positivity between patients and controls. About 6 cases (4.8%, n = 6) showed anti-Toxoplasma IgM antibodies, while the control group had no cases of Toxoplasma IgM positivity. Toxoplasma IgM negativity is significantly higher in patients (42.7%, n = 53) compared to controls (100%, n = 449). 52.4% of IgM data in patients (n = 65) is missing. The unavailability of tests in the hospital is due to the absence of completed tests and a lack of DS-EIA-ANTI-TOXO-M capture kits, which are necessary for the enzyme immunoassay. Antibodies targeting *T. gondii* IgG were examined to determine infection presence. 1.0% (n = 6) tested positive for IgM and 87.6% (n = 502) tested negative. 11.3% (n = 65) had missing data. The P-value is less than 0.001, indicating a significant difference in IgM antibodies between the cases and controls. **Table 2** summarizes the antibody pattern among the groups studied.

Table 2: The antibody pattern among the studied groups, n = 573

Parameters		Cases N = 124		Controls N = 449		Total N = 573		P value
		Count	%	Count	%	Count	%	
IgG	positive	121	97.6%	0	0.0%	121	21.1%	< 0.001
	negative	2	1.6%	449	100.0%	451	78.7%	
	unavailable	1	0.8%	0	0.0%	1	0.2%	
IgM	positive	6	4.8%	0	0.0%	6	1.0%	< 0.001
	negative	53	42.7%	449	100.0%	502	87.6%	
	unavailable	65	52.4%	0	0.0%	65	11.3%	

*P value was calculated by Pearson Chi-Square test

Demographic variables (age, gender) were explored as potential risk factors for infection with *Toxoplasma gondii*

Figure 4 and **Table 3** show differences in demographics (gender and age) between two groups (positive and negative) in a sample of 573 people with the age range of 4 to 44. There is a noticeable difference in gender distribution between the positive (n = 124) and negative (n = 449) groups, supported by a significant p-value of 0.02. The positive group has more females (73.4%, n = 91) than males (26.6%, n = 33). The negative group has a balanced gender distribution: 61.9% females (n = 278) and 38.1% males (n = 171). Significant age difference observed between groups (p-value = 0.001). The positive group is mostly older, with an average age of 23.27 (SD = 17.90) and a middle age of 29.50, ranging from 5 to 47. The negative group is mostly younger, with an average age of 15.54 (SD = 15.44) and a median age of 7. This data reveals a connection between the condition studied and age and gender, prompting further investigation into the complex dynamics and potential causality involved. The positive group seems to attract older women more, so we should investigate why and how this demographic is.

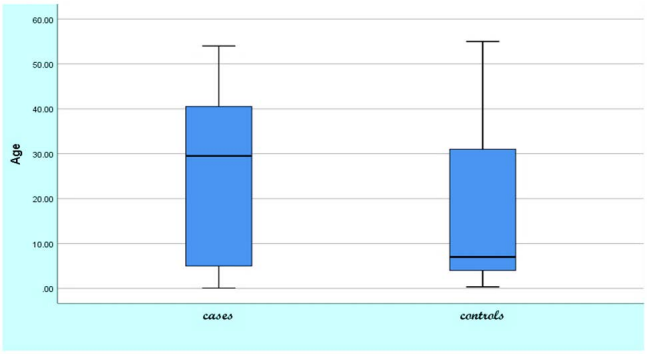

Figure 4: Age distribution among the studied groups

Table 3: Demographic criteria among the studied groups, n = 573

Parameters		Positive N = 124		Negative N = 449		Total N = 573		P value
		Count	%	Count	%	Count	%	
Gender	Females	121	97.6%	0	0.0%	121	21.1%	0.02
	Males	91	73.4%	278	61.9%	369	64.4%	
Age	Mean + SD	23.27 + 17.90		15.54 +15.44		17.21 +16.30		0.001
	Median (IQR)	29.50 (5: 47)		7 (4 :44)		7 (4:45)		

*P value was calculated by Fisher's Exact Test or Mann-Whitney U test wherever suitable, highlighted values are statistically significant and related to the condition being studied

Subgroup analysis of the *Toxoplasma gondii* seroprevalence among female seropositivity by age, marital status, gravida, parity, and abortion

Regarding the prevalence of *T. gondii* seropositivity among the female cases studied (n = 91), interesting patterns emerge across different demographics and reproductive factors. The highest prevalence (68.13%) was among women aged 31 and above, followed by those under 20 years (27.47%), and the lowest was observed among those aged 20-30 years (4.39%). Age may increase vulnerability to *T. gondii*. Married females had a prevalence of 58.24% for *T. gondii* seropositivity, while unmarried females had a prevalence of 41.76%. In a study of 53 females, the analysis of "Gravida" (total number of pregnancies) reveals that 52.83% had 4 or more pregnancies, 35.85% had 2-3 pregnancies, and 11.32% had 0-1 pregnancies. This suggests a trend towards higher pregnancy numbers in this subgroup. Parity showed that women with 2-4 pregnancies had the highest prevalence at 52.83%, while those with 5 or more pregnancies had the lowest at 7.55%. Abortion history showed a clear difference in prevalence: 75.5% of those who had abortions were seropositive, compared to only 24.5% among those who did not. This difference is notable and should be further investigated for any possible connection between *T. gondii* seropositivity and abortion history. In **Table 4**, the highest percentage was for the age group over 30 years, with most being married. The most common groups for gravida and parity were ≥ 4 and 2-4, respectively. About 75% of the group had a history of abortion.

Table 4: Subgroup analysis of prevalence of *T. gondii* Seropositivity in female cases n = 91

Sub-group		No.	Prevalence
Age	<20	25	27.47%
	20-30	4	4.39%
	≥31	62	68.13%
Married Female		53	58.24%
Unmarried Female		38	41.76%
Gravida (Total no. of pregnancies)	0-1	6	11.32%
	2-3	19	35.85%
	≥4	28	52.83%
Parity (n = 53) (No. of complete pregnancies)	Zero	7	13.20%
	1	14	26.42%
	2-4	28	52.83%
	≥5	4	7.55%
Abortion (n = 35)	No	13	24.5%
	Yes	40	75.5%

Percentage of abortion among married females of Toxoplasmosis infection

Table 5 explores abortion rates among 53 married females with Toxoplasmosis infection. The data shows that 54.3% of participants had three or more abortions, while 24.5% had none and 30.2% had 1-2 abortions. The high number of abortions (≥3) suggests a need to investigate factors and health implications related to Toxoplasmosis infection. 75.0% of abortions occur during the first trimester, which is known for higher risks. However, the 17.5% in the third trimester requires a careful investigation due to the higher risks and complexities involved in late-stage pregnancy terminations. Only 7.5% of abortions occur in the second trimester, which is consistent with general trends. However, considering the high number of first-trimester abortions and a significant percentage in the third trimester, a more detailed analysis could shed light on the impact of Toxoplasmosis on pregnancy sustainability and outcomes. The data suggests a possible connection between Toxoplasmosis and abortion. It emphasizes the need to understand why many women in this group have multiple abortions so that appropriate healthcare strategies can be created.

Table 5: Percentage of abortion among married females of Toxoplasmosis infection, n = 53

		Count	%
Abortion	0	13	24.5%
	1-2	16	30.2%
	≥3	24	54.3%
	Total	53	100%
Abortion in the trimester of pregnancy	1st trimester	30	75.0%
	2nd trimester	3	7.5%
	3rd trimester	7	17.5%
	Total	40	100%

Important clinical picture suggestive of Toxoplasmosis infection

The dataset in **Table 6** shows clinical manifestations of Toxoplasmosis in 124 cases. Manifestations can appear in various clinical presentations, especially when infection occurs during pregnancy, affecting fetal development. "Developmental delay" is the most prevalent condition in the dataset, affecting 13 instances or 10.5% of the population. A delay like this can affect a child's development in many ways, including motor skills, language, and social skills. The high prevalence of "congenital abnormalities" in 9 cases (7.3%) is concerning due to potential health issues as these individuals age. Seizure disorder was observed in 7 cases, representing 5.6% of the sample. This condition poses challenges for managing neurological and overall health. In addition, epilepsy and intrauterine growth retardation (IUGR) were observed in 5 cases (4.0%) and 4 cases (3.2%) respectively. Both disorders may need medical treatment and procedures to manage and alleviate health difficulties. Additionally, "Autism" is found in three cases, making up 2.4% of the total sample. This suggests the need for personalized developmental and educational interventions. Table 6 displays clinical signs of Toxoplasmosis infection in the cases.

Table. 6: Clinical picture suggestive of Toxoplasmosis infection among the cases, n = 124

Picture	No.	%
Epilepsy	5	4.0%
Autism	3	2.4%
Seizures disorder	7	5.6%
Developmental delay	13	10.5%
Congenital abnormalities	9	7.3%
Intrauterine growth retardation	4	3.2%
Other cases without symptom	83	67%
Total	124	100%

DISCUSSION

Toxoplasmosis is one of the most common diseases worldwide caused by a coccidian parasite, *Toxoplasma gondii*. The seroprevalence of *T. gondii* ranges from 10 to 80% among different regions of the world depending on cultural and eating habits, hygiene, as well as environmental conditions[15-18]. The present retrospective study conducted at King Fahad Hospital offered noteworthy insights into the seroprevalence and risk variables associated with *T. gondii* infection in the Al-Baha region. Our study represents the first published data analysis of toxoplasmosis seroprevalence in the Al-Baha region leveraging a thorough analysis of patient files. With a total sample size of 693 and after excluding 120 patients the final sample size of the study was 573 patients, the study elucidated several key findings and patterns worth providing critical insights into the seroprevalence, demographic characteristics, and obstetric implications of the infection in the population of Al-Baha region.

The prevalence of *T. gondii* infection, elucidated in our study, provides a compelling insight into the widespread nature and potential risk factors of the infection within the studied demographic in the Al-Baha region. A prevalence rate of 22%, with a conspicuous lean towards female and older demographics in the positive cases. Particularly when juxtaposed with findings from various other studies within Saudi Arabia. For instance, a study conducted in Makkah, Saudi Arabia, and Al-Madinah Al-Munawara reported a similar *T. gondii* seroprevalence of 22.4% and 21.3%, respectively[19-24]. This resemblance in prevalence rates under-scores the pertinence of exploring common risk factors and implementing region-specific interventions to mitigate potential health risks, particularly among sensitive populations like pregnant women. Alanazi et al. (2017), in the Ad-Dawadimi, reported a substantially higher seroprevalence of approximately 40.9% across diverse social and age groups[21]. This disparity in prevalence across regions, despite a somewhat consistent demographic, sparks inquiries into potential regional-specific risk factors or exposure variables. The gender and age dynamics, particularly the higher seroprevalence amongst females and older individuals in our study, are somewhat mirrored by studies like Al-Mohammed et al. (2010) in the Eastern Province and Al-Harthi et al. (2006) in the Western Region, suggesting a potentially consistent pattern wherein gender and age emerge as pivotal variables in *T. gondii*

seroprevalence across various regions and populations[23,24]. The notable gender disparity, particularly the elevated prevalence among females in our study, echoes findings from Ghazi et al. (2002), which also reported a higher seroprevalence among females in Saudi Arabia (35.9%)[25]. This consistent gender disparity across various studies signals the imperative to explore gender-specific risk factors and mechanisms influencing *T. gondii* transmission and susceptibility. Considering the gender and age dynamics observed in our study, exploring how these risk factors particularly intertwine with the lifestyles and behaviors of different demographic cohorts could offer nuanced insights into targeted preventive strategies. A study conducted by Al-Zaheb and Al-Amer (2017), pointed towards a lower prevalence (9.4%) among a specific demographic, female students at a university in Northern Saudi Arabia, and this proved our finding[26]. Also, a study by Dawet et al. (2022) in Al-Kharj, Saudi Arabia, pointed towards a high prevalence among a specific demographic, females younger than 26 years of age, implying that the gender dynamics might be influenced by specific lifestyle, exposure, or biological variables, potentially intertwined with sociocultural norms and practices[27]. Thus, while our findings nestle within the broader narrative of *T. gondii* seroprevalence in Saudi Arabia, they also underscore the criticality of delving deeper into understanding the regional, demographic, and socio-behavioral intricacies that shape the patterns and disparities observed in *T. gondii* seroprevalence, paving the way for targeted, contextually relevant, and effective public health interventions and strategies. On the reproductive front, our study illuminated a pronounced 52.83% *T. gondii* seroprevalence among females with 4 or more pregnancies, hinting at a possible trend of increased seropositivity with higher parity. Olariu et al. (2020) underscore a potential correlation or even causative relationship between *T. gondii* seropositivity and gravidity[28]. Furthermore, our study also unveiled a striking correlation between *T. gondii* seropositivity with a history of abortion. The substantially higher prevalence of *T. gondii* seropositivity among women with ≥3 abortions and the stark contrast in seroprevalence among those with a history of abortion (75.5% seropositive) compared to those without (24.5%) underscores a potential correlation or even causative relation between *T. gondii* seropositivity and abortion history. Brackets mirror studies like Al-Adhroey et al. (2019), which also identified a positive correlation between *T. gondii* infection and a history of abortion in Dhamar district, Yemen[29]. This is contradicted by Al-Yami et al. (2021) study, which found that there is no association between seropositivity for *T. gondii* and miscarriage. The underlying causality or associations between *T. gondii* infection, parity, and abortion history might be interwoven with socio-behavioral, environmental, and healthcare access variables, necessitating a more nuanced and multidimensional exploration in subsequent research[30]. Based on our study results, there are several key findings regarding the presence of *T. gondii* infection and its association with demographic variables:

- **Antibodies Pattern:** Among the studied groups, 97.6% (121 out of 124) of the cases tested positive for IgG antibodies, while none of the controls tested positive. This indicates a strong association between IgG positivity and the condition being studied (cases). In contrast, only 4.8% (6 out of 124) of cases tested positive for IgM antibodies, compared to none in the control group.
- **Gender Distribution:** There is a significant difference in gender distribution between the Positive and Negative groups. In the Positive group, females constitute 73.4% (91 out of 124), while males make up only 26.6% (33 out of 124). In contrast, the Negative group has a more balanced gender distribution, with females accounting for 61.9% (278 out of 449) and males comprising 38.1% (171 out of 449). The p-value of 0.02 suggests a statistically significant association between gender and *T. gondii* infection.
- **Age Distribution:** There is also a significant difference in age distribution between the Positive and Negative groups. The Positive group has an older demographic, with a mean age of 23.27 years and a median age of 29.50 years (IQR: 5 to 47). On the other hand, the Negative group consists mainly of younger individuals, with a mean age of 15.54 years and a significantly lower median age of 7 years (IQR: 4 to 44). The p-value of 0.001 indicates a statistically significant association between age and *T. gondii* infection.

These findings suggest that being female and older may be a risk factors for *T. gondii* infection in this population. Further investigation is needed to understand the underlying mechanisms and potential causality behind these associations. Our study indicates various clinical manifestations, particularly developmental delay (10.5%), congenital abnormalities (7.3%), seizure disorders (5.6%), Epilepsy (4.0%), Intrauterine growth retardation (3.2%), and Autism (2.4%) emphasizing the multifaceted health challenges posed by *T. gondii* infection. Elzeky et al. (2022) also identified neurodevelopmental disorders as a significant concern in *T. gondii*-infected populations in Egypt[31]. This underscores the need for comprehensive antenatal care, early screening, early identification, and intervention strategies to support these cases and targeted interventions to manage and potentially mitigate the adverse health outcomes stemming from *T. gondii* infection, particularly considering the lifelong impact of conditions like congenital abnormalities, and developmental delay, and cognitive impairment, which is also highlighted by Al Malki et al. (2021), who delineated the potential impact of congenital toxoplasmosis on autism outcomes in children in Jeddah. This regional parallelism underscores the potential transboundary consistency in clinical manifestations, emphasizing the need to navigate *T. gondii* management from a global health perspective[32]. Overall, these findings suggest a relatively high prevalence rate of *T. gondii* infection among patients in the Al-Baha region and highlight the importance of further investigation into risk factors associated with seroprevalence. While the above comparisons offer a glance into the prevalent patterns and dynamics of *T. gondii* infection across various studies, it's imperative to acknowledge the socio-cultural, environmental, and healthcare access disparities that might influence these patterns. Additionally, understanding how these factors collectively or independently interact with *T. gondii* seroprevalence and associated risk variables will enhance the capacity to develop, implement, and optimize tailored prevention and management strategies.

CONCLUSION

The retrospective study in the Al-Baha region revealed *T. gondii* infection prevalence and identified associative patterns and risk variables, providing a basis for future research and interventions. In the future, we need to address the limitations found in data and methodology by using more rigorous research designs. Studying diverse populations, locations, and risk factors is important for understanding *T. gondii* dynamics. Translating research findings into public health strategies and interventions is important in reducing the impact of *T. gondii* infection. By conducting collaborative research, using multiple disciplines and robust methodologies, we can better understand and control *T. gondii* infection, leading to improved public health outcomes. Saudi Arabia can reduce *T. gondii* infection and improve citizen well-being by implementing comprehensive strategies, resulting in a healthier population.

LIMITATIONS

The study on *T. gondii* infection in Al-Baha is limited due to its retrospective nature, geographical and demographic bias, and lack

of data on characteristics affecting seroprevalence. The study's single hospital and location may also lead to skewed results. Inadequate testing kits and sensitivity and specificity limits also affect reported prevalence and antibody distribution. The absence of maternal toxoplasmosis screening data makes it difficult to assess preventative strategies and determine the population prevalence of *T. gondii* infection. Limited risk factor data also hinders the development of tailored therapies and educational efforts.

RECOMMENDATIONS

The study suggests that Saudi Arabia's *T. gondii* screening and prevention programs could be improved by recording infection risk variables in patient records. Healthcare providers can assess prevalence and risk factors, focusing on cleanliness and food safety. Screening programs can identify high-risk individuals and provide treatment, safeguarding the population and enhancing public health. Careful data recording in patient files helps researchers understand infection dynamics, develop prevention strategies, and analyze larger datasets. This rigorous data entry enhances the ability to analyze, control, and potentially eradicate toxoplasmosis risk factors.

Authorship Contribution:

Susan Ahmed Almalki: Methodology, Software, Investigation, Resources, Data Curation
Eman Khalaf Mohammad: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Visualization, Supervision, Project Administration
Shazia Shaheen Mir: Methodology, Validation, Writing – Original Draft, Writing – Review & Editing, Project Administration
Omar Asad Azhar: Validation, Visualization
Raed A Alharbi: Validation, Visualization
Hanan Eid Alyahyawi: Validation, Visualization
Shaia S R Almalki: Conceptualization, Validation, Supervision, Project Administration, Funding Acquisition.

Funding: The authors thank the Deputyship for Research and Innovation, Ministry of Education in Saudi Arabia, for funding this research work through project number MOE-BU-1-2020.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. This research contained no personally identifiable information. Data from routine monitoring that had been anonymized were used in this secondary analysis.

Ethical Approval: Permission was taken from the Institutional Research and Ethics Committee (Scientific Research Committee at King Fahad Hospital in Al-Baha, Saudi Arabia, IRB Approval: KFH/IIRB23052023/4) Date 23/05/2023.

Potential Conflicts of Interest: None

Competing Interest: None

Acceptance Date: 19-02-2024

REFERENCES

1. Iddawela D, Vithana SMP, Ratnayake C. Seroprevalence of toxoplasmosis and risk factors of *Toxoplasma gondii* infection among pregnant women in Sri Lanka: a cross sectional study. BMC Public Health 2017; 17: 930.
2. Iribarren D, Martín-Gamboa M, O'Mahony T, et al. Screening of socio-economic indicators for sustainability assessment: a combined life cycle assessment and data envelopment analysis approach. Int J Life Cycle Assess 2016; 21: 202-14.
3. Al-Malki ES. Toxoplasmosis: stages of the protozoan life cycle and risk assessment in humans and animals for an enhanced awareness and an improved socio-economic status. Saudi J Biol Sci 2021; 28(1): 962-9.
4. Faral-Tello P, Pagotto R, Bollati-Fogolín M, et al. Modeling the human placental barrier to understand *Toxoplasma gondii*' s vertical transmission. Front Cell Infect Microbiol 2023; 13: 1130901.
5. Bollani L, Auriti C, Achille C, et al. Congenital toxoplasmosis: the state of the art. Front Pediatr 2022; 10: 894573.
6. Robert-Gangneux F, Dardé M-L. Epidemiology of and diagnostic strategies for toxoplasmosis. Clin Microbiol Rev 2012; 25(2): 264-96.
7. Kodym P, Malý M, Beran O, et al. Incidence, immunological and clinical characteristics of reactivation of latent *Toxoplasma gondii* infection in HIV-infected patients. Epidemiol Infect 2015; 143(3): 600-7.
8. Maspi N, Nayeri T, Moosazadeh M, et al. Global seroprevalence of *Toxoplasma gondii* in Camelidae: A systematic review and meta-analysis. Acta Parasitol 2021; 66: 733-44.
9. Nayeri T, Sarvi S, Moosazadeh M, et al. The global prevalence of *Neospora caninum* infection in sheep and goats that had an abortion and aborted fetuses: A systematic review and meta-analysis. Front Vet Sci 2022; 9: 870904.
10. Nayeri T, Sarvi S, Moosazadeh M, et al. Global prevalence of *Toxoplasma gondii* infection in the aborted fetuses and ruminants that had an abortion: A systematic review and meta-analysis. Vet Parasitol 2021; 290: 109370.
11. Tavalla M, Asgarian F, Kazemi F. Prevalence and genetic diversity of *Toxoplasma gondii* oocysts in cats of southwest of Iran. Infect Dis Health 2017; 22(4): 203-09.
12. Syarifah I. The Correlation between Meat Consumption with the Risk of Contracting *Toxoplasma Gondii* with the Occurrence of Patients with Toxoplasmosis in Bogor Aquatreat Clinic, Indonesia. Indian J Public Health Res Dev 2020; 11(10): 249-55.
13. Ducrocq J, Simon A, Lemire M, et al. Exposure to *Toxoplasma gondii* through consumption of raw or undercooked meat: a systematic review and meta-analysis. Vector Borne Zoonotic Dis 2021; 21(1): 40-9.
14. García GA, Davidson R, Jokelainen P, et al. Identification of oocyst-driven *Toxoplasma gondii* infections in humans and animals through stage-specific serology—current status and future perspectives. Microorganisms 2021; 9(11): 2346.
15. Salih JM, Mero WMM, Eassa S. Seroprevalence and some demographic factors associated with *Toxoplasma gondii* infection among male population in Duhok Province/Iraq. Baghdad Sci J 2020; 17(2): 431.
16. Alzaheb RA. Seroprevalence of *Toxoplasma gondii* and its associated risk factors among women of reproductive age in Saudi Arabia: a systematic review and meta-analysis. Int J Womens Health 2018; 10: 537-44.
17. Yektaeian N, Malekpour A, Atapour A, et al. Genetic immunization against toxoplasmosis: A review article. Microb Pathog 2021; 155: 104888.
18. Ahaduzzaman M, Hasan T. Seroprevalence of *Toxoplasma gondii* infection in sheep and goats from different geographical regions of the world: Systematic review and meta-analysis. Transbound Emerg Dis 2022; 69(6): 3790-822.
19. Mohamed K, Bahathiq A, Degnah N, et al. Detection of *Toxoplasma gondii* infection and associated risk factors among pregnant women in Makkah Al Mukarramah, Saudi Arabia. Asian Pac J Trop Dis 2016; 6(2): 113-9.

20. Imam NF, Esra'a A, Attia AA. Seroprevalence of *Toxoplasma gondii* among pregnant women in Almadinah Almunawwarah KSA. J Taibah Univ Med Sci 2016; 11(3): 255-59.
21. Alanazi AD, Alyousif MS, Alomar SA, et al. SEROPREVALENCE AND RISK FACTORS OF *TOXOPLASMA GONDII* INFECTION AMONG PREGNANT WOMEN IN AD-DAWADIMI GENERAL HOSPITAL, KINGDOM OF SAUDI ARABIA. J Egypt Soc Parasitol 2017; 47(2): 355-62.
22. Imam A, Al-Anzi FG, Al-Ghasham MA, et al. Serologic evidence of *Toxoplasma gondii* infection among cancer patients. A prospective study from Qassim region, Saudi Arabia. Saudi Med J 2017; 38(3): 319-21.
23. Alanazi FI, Hassan TM, Alanazi WM. Seroprevalence of Toxoplasma gondii among pregnant Saudi woman in Arar, Northern borders province, Saudi Arabia. Kasr Al Ainy Med J 2017; 23(2): 104.
24. Al-Harthi SA, Jamjoom MB, Ghazi HO. Seroprevalence of Toxoplasma gondii among pregnant women in Makkah, Saudi Arabia. Umm Al-Qura Univ J Sci Med Eng 2006; 18(2): 217-27.
25. Ghazi HO, Telmesani AM, Mahomed MF. TORCH agents in pregnant Saudi women. Med Princ Pract 2002; 11(4): 180-2.
26. Alzaheb RA, Al-Amer O. The seroprevalence and risk factors of toxoplasmosis among female undergraduate university students in Saudi Arabia. Oman Med J 2017; 32(6): 486-91.
27. Dawet A, Yusuf K, Golnaan C, et al. Sero-Prevalence of *Toxoplasma gondii* in Pregnant Women Attending Ante Natal Care in Jos University Teaching Hospital (JUTH). J Infect Dis Epidemiol 2022; 8: 285.
28. Olariu TR, Ursoniu S, Hotea I, et al. Seroprevalence and risk factors of Toxoplasma gondii infection in pregnant women from Western Romania. Vector Borne Zoonotic Dis 2020; 20(10): 763-7.
29. Al-Adhroey AH, Mehrass AA-KO, Al-Shammakh AA, et al. Prevalence and predictors of Toxoplasma gondii infection in pregnant women from Dhamar, Yemen. BMC Infect Dis 2019; 19(1): 1089.
30. Al-Yami FS, Dar FK, Yousef AI, et al. A pilot study on screening for gestational/congenital toxoplasmosis of pregnant women at delivery in the Eastern Province of Saudi Arabia. Saudi Pharm J 2021; 29(4): 343-50.
31. Elzeky SM, Nabih N, Abdel-Magied AA, et al. Seroprevalence and genetic characterization of *Toxoplasma gondii* among children with neurodevelopmental disorders in Egypt. J Trop Med 2022; 2022: 2343679.
32. Al Malki JS, Hussien NA, Al Malki F. Maternal toxoplasmosis and the risk of childhood autism: serological and molecular small-scale studies. BMC Pediatr 2021; 21(1): 133.